Printability of V-Si-B Alloys: Mechanical Properties and Oxidation Performance

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There nearly is no other industry placing such high demands on materials as aircraft construction. Due to the mature design of the aircraft engines, further competition will take place with innovative materials and manufacturing processes. In the vicinity of the combustor, where engine parts are burden with temperatures higher than 500 °C, Ni-based superalloys have been state-of-the-art for many years. However, Ni-based superalloys come along with a high density (~ 8.5 g/cm^3). Weight reduction is an important issue to achieve the target of increased thermodynamic efficiency including less fuel consumption and a reduced amount of exhaust emissions. To this end, research activities focus on new light-weight materials with good high-temperature properties to increase the thrust-to-weight ratio in aircraft engines by replacing Ni-based superalloys. Vanadium points out as an interesting candidate, since it offers the lowest density (ρ = 6.11 g/cm^3) in comparison to other high-melting metals. Moreover, alloyed with Si and B, a multi-phase microstructure consisting of a vanadium solid solution (V_{ss}) phase next to the intermetallic phases V_3Si and V_5SiB_2 [1,2] forms, which offers a low ductile-brittle-transition as well as enhanced high temperature strength and creep resistance next to an improved oxidation resistance [1]. However, conventional ingot metallurgical processing of V-Si-B material and subsequent machining is energy- and time-consuming due to the different behavior of the ductile solid solution phase and the brittle silicides. This work presents the first study on additive manufacturing of a high melting point near-eutectic V-based alloy via additive manufacturing (AM) process. The feasibility of printing pre-alloyed V-Si-B powder material was demonstrated. V-Si-B powder was manufactured via gas atomization (GA) process out of solid raw materials meeting the requirements for AM regarding flowability and particle size. After developing suitable process parameters for the generation of crack-free samples, the microstructure of the materials was analyzed in detail using SEM/EDS and EBSD analyses. An overview about the ambient and high temperature material properties of a V-9Si-5B alloy is given. In terms of high-temperature mechanical properties, the brittle-to-ductile transformation temperature (BDTT) and the creep rate at a potential application temperature were determined as well as first investigations on the oxidation resistance.

References

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